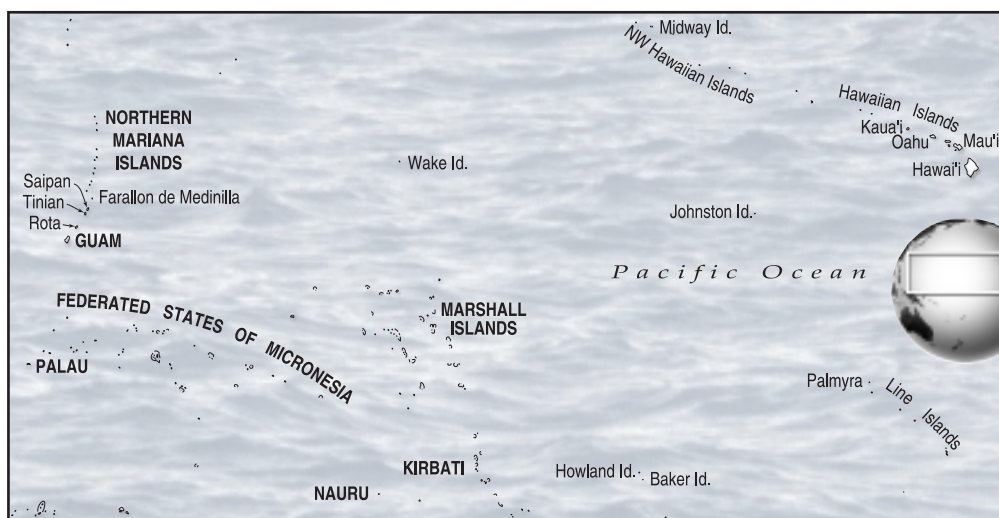


13. STATUS OF CORAL REEFS IN THE HAWAIIAN ARCHIPELAGO

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ABSTRACT

Approximately 85% of all US coral reefs occur within the Hawaiian Archipelago. The reefs that make up this region stretch over 2,000km and contain a majority of the reef types seen across the Pacific. They are characterised by their isolation from other Pacific reefs and high endemism across most phyla. The Archipelago consists of two distinct regions: the Main Hawaiian Islands (MHI) made up of populated, high, volcanic islands with non-structural reef communities and fringing reefs abutting the shore, and the Northwestern Hawaiian Islands (NWHI) consisting of mostly uninhabited atolls and banks accounting for the majority (69%) of US reefs. The differences in anthropogenic impacts on these two regions are striking. The MHI are urbanised with extensive coastal development and associated runoff; overfishing for food and marine ornamentals, alien species invasions, and marine debris are each of increasing concern. The NWHI coral reefs are affected primarily by marine debris and the impacts from lobster and bottom fisheries. Concerns exist over current and proposed ecotourism activities and new fisheries. Recent coral reef management initiatives include new forms of MPAs related to marine ornamental collection and tourism, as well as assessment and long-term monitoring programmes involving active partnerships between scientists, community groups and management agencies.



No. islands, islets & coral cays		Land Area (km ²)	Reef Area (km ²)	Reef Type
Hawaii Island	(4)	10,433	253	Fringing, reef communities
Maui*	(18)	3,037	1421	Fringing, banks, reef communities
O'ahu	(15)	1547	504	Barrier, fringing, platform
Kaua'i#	(5)	1612	348	Barrier, fringing, reef communities
NWHI	(29)	14	8,318	Atolls, fringing, platform, banks

Basic geographic details of the islands covered by this report

* Maui includes the high islands of Maui, Lana'i, Moloka'i & Kaho'olawe

Kaua'i includes the high islands of Kaua'i and Ni'ihau.

INTRODUCTION

The Hawaiian Archipelago stretches over 2,400km from 19–28°N latitude and is one of the most isolated, yet populated areas on earth. Therefore regional and global impacts seen in many other areas are of less concern than the increasing impacts of urban-related activities. The geographic isolation has lead to many endemic species in many marine phyla, including corals. There are 8 large islands and 124 small islands, reefs and shoals in 2 distinct regions: the Northwestern Hawaiian Islands (NWHI) consisting of mainly uninhabited atolls and banks containing 60% of US reefs; and the populated, high, volcanic Main Hawaiian Islands (MHI) surrounded by reef communities, fringing reefs and two barrier reefs

MHI

These consist of high volcanic islands which range from 7 million years old (Kaua'i) to active lava flows on the east side of the 'Big Island' of Hawaii. The Polynesian peoples who first settled these islands had strong ties to coral reefs; reef resources provided food, medicines, and building materials, and were a major part of cultural and social customs in ancient Hawaii.

Broad-scale degradation of Hawaiian coral reefs began 100-200 years ago with the expansion of Western influence bringing livestock and agriculture and contributing to erosion and sediment flow onto the reefs. Dredging and reclamation of nearshore reefs for military, commercial, and residential use by over 1.2 million inhabitants has resulted in more damage. Streams have been channelised and increased paving of land area has increased the rate of water runoff near the urban centres. Despite these changes, most of the nearshore reefs remain in fair to very good condition. Coral reefs are a critical component of the \$800 million per year marine tourism industry, providing white sandy beaches, surfing and diving sites, and recreational, subsistence, and commercial fishing.

	Population (Distribution)	Population per km ²	GDP in US\$ (per capita)	Tourists/yr
Hawaii Island	138,400 (27% Hilo)	13	\$2,400 million (\$17,341)	1,255,480
Maui, Kaho'olawe, Lana'i & Moloka'i	100,504 (17% Kahului)	33	\$2,800 million (\$30,648)	2,376,330
O'ahu	871,800 (43% Honolulu)	564	\$26,800 million (\$30,741)	5,002,530
Kaua'i & Ni'ihau	56,665 (14% Kapa'a)	35	\$1,200 million (\$21,177)	992,780
NWHI	164 (99% Midway)	11	Not applicable	5,000

Basic demographic and economic data for islands of the Hawaiian Archipelago.

NWHI

These extend for more than 1600km northwest of Kaua'i, starting with Nihoa and Necker (7 and 10 million years old) to Midway and Kure atolls (28 million years old). Most of the atolls are uninhabited, although Midway, Kure and French Frigate Shoals have all been military bases. The US Fish and Wildlife Service (USFWS) manages the Midway National Wildlife Refuge and a relatively large ecotourism operation has started on Midway. The remainder of the NWHI are part of the State of Hawaii and the majority are within the Hawaiian Islands National Wildlife Refuge, established by President Roosevelt in 1909, and currently administered by the USFWS. The NWHI reefs are in very good to excellent condition, but are subject to species-specific over-fishing.

STATUS OF CORAL REEFS

MHI

The coral reefs of the Hawaiian Archipelago are considered to be a separate eco-region because of their isolation from other Pacific reefs. There are 55 species of hard (scleractinian) corals in Hawaii, with over 25% of these being endemic. The highest diversity of corals in the MHI occurs around the islands of O'ahu and Hawaii. Live coral cover ranged from 4-50% at the 25 sites between 2-3m and 10m depths surveyed by the Hawaii Coral Reef Assessment and Monitoring Program (CRAMP) in 1999-2000. Marine invertebrate biodiversity and endemism are relatively high in Hawaii, with over 100 species of sponges, 1071 species of marine molluscs, 884 species of crustaceans, and 278 species of echinoderms. The Hawaiian Islands are thought to support over 400 algal species, many of which are endemic, as well as one endemic seagrass, *Halophila hawaiiiana*. There are 557 species of reef and shore fishes in Hawaii; very low compared to other Indo-West Pacific reefs (e.g. >2,500 fish species in the Philippines). Hawaii has the highest percentage of endemics (24.3%) in the world, and these endemics are often dominant members of Hawaiian reef communities. The low number of species and even families is due to the geographic and oceanographic isolation from other reefs far to the west and south.

NWHI

There are 22 hard coral species and about 200 algal species known at present, but more complete surveys are expected to increase these numbers substantially. The *Acropora* species found here do not occur in the MHI. French Frigate Shoals, Pearl and Hermes Reef, and Maro Reef have the highest coral biodiversity and cover, but coral cover is generally low throughout the NWHI. Growth rates for corals in the northern portion of the chain are significantly slower than farther south raising concern about potential recovery from human impacts. The endemic seagrass *Halophila hawaiiensis* has been found at Midway Atoll and may occur elsewhere in the NWHI. There have been no recent surveys of other invertebrates, but rapid ecological assessments of the NWHI are scheduled for October 2000.

Reef and shore fish diversity is lower in the NWHI, with 266 species recorded from Midway Atoll. The cooler waters, lack of critical habitats (and lower sampling effort) may be the reasons for these low numbers. The fish community in the NWHI is different from the MHI with reduced abundance of herbivores (mostly surgeonfishes) and more predators (mostly jacks, sharks, goatfishes, scorpionfishes, and bigeyes). The fish assemblage in the NWHI is dominated both in numbers and biomass by carnivores.

Bleaching Events

Hawaiian reefs escaped the widespread bleaching that devastated many Pacific reefs during the last decade, although Hawaiian corals are susceptible and local rises in water temperatures (or increased UV penetration) have caused occasional bleaching. Following three days of exceptionally calm and warm conditions in September 1996, many shallow corals in Kane'ohe Bay and Kailua Bay on O'ahu, showed partial or complete bleaching that resulted in limited coral mortality.

Disease

Coral diseases and tumours have been found on most major coral species of the MHI (*Porites lobata*, *P. compressa*, *Montipora capitata*, *M. patula*, and *Pocillopora meandrina*). Surveys from 1991 to 1998 showed a mean frequency of 22% of diseased corals over a range of depths and habitats. At some sites, up to 60% of colonies were affected with disease covering up to 32% of the surface of the dominant *P. lobata*. Like other areas, the incidence of coral disease in Hawaii does not appear to be related to anthropogenic stress e.g. pollution, proximity to urban centres, and no major disease outbreaks have yet occurred in Hawaii.

Turtle tumours (fibropapillomas) were rarely seen on Hawaiian green sea turtles (*Chelonia mydas*) prior to 1985, but the incidence has increased drastically, and this disease now commonly afflicts turtles on Kaua'i, O'ahu, Moloka'i, and Maui; up to 60% of turtles in Kane'ohe Bay have tumours.

STATUS OF REMOTE CORAL REEFS IN THE US INSULAR PACIFIC

Jim Maragos and Rusty Brainard

The US has jurisdiction over 9 remote islands in the tropical Pacific: Howland and Baker Islands in the Phoenix Islands; Jarvis Island, Palmyra Atoll, Johnston Atoll, and Kingman Reef in the northern Line Islands; and Wake Atoll north of the Marshall Islands. Midway Atoll and Rose Atoll are off Hawaii and American Samoa respectively and are also covered elsewhere. Wake, Midway, Kingman, Palmyra, Rose, and Johnston are coral atolls, while Jarvis, Howland, and Baker are low coral islands surrounded by narrow fringing reefs. These islands were uninhabited until 200 years ago, and now there are people only on Wake, Johnston and Midway. The Nature Conservancy is establishing an ecotourism facility at Palmyra Atoll, and the USFWS authorises compatible ecotourism in the Midway National Wildlife Refuge (NWR). Midway, Howland, Baker, Palmyra, Kingman, and Jarvis were former US military bases, and Johnston and Wake are still active militarily, although there are plans to close them. Johnston, Rose, Howland, Baker, and Jarvis are NWRs, and Kingman and Palmyra are being proposed as NWRs. Rose NWR is jointly administered by American Samoa and the USFWS. All of these reefs have been surveyed since 1995, and they are all in near pristine condition, as there are no anthropogenic impacts, except for occasional ship groundings, and illegal fishing.

Rose Atoll

Dissolved iron concentrations, algae, giant clams, sea cucumbers, and fish have been monitored several times following the grounding of a long-line fishing vessel at Rose Atoll NWR in late 1993. Additional monitoring sites for giant clams and corals were established during the 1999-2000 ship debris removal from the atoll. Monitoring and observations documented the impacts of the fuel spill and iron enrichment on reef habitats and helped to justify the funds to remove the wreckage. About 80% of the ship debris have been removed, leading to recovery of giant clams (corals and coralline algae, and reduction of invading blue-green algae stimulated by iron enrichment.

Johnston and Wake Atolls

The US military has sponsored ecological monitoring programmes at Johnston Atoll during the past 20 years, including fish populations and seabirds. In 1997, coral reef monitoring activities were extended to Wake Atoll (and in 2000 to Johnston Atoll where permanent coral monitoring transects were established during installation of mooring buoys). Both atolls suffered extensive damage from dredging and filling during World War II, but reefs have recovered and are now in healthy condition.

Howland, Baker Jarvis, Kingman, and Palmyra

These were surveyed in early 2000 and found to be in relatively pristine condition except for some over-fishing. The disposal of military debris off the west side of Baker and the west lagoon of Palmyra may have stimulated some invasive algal growths. Only small sharks were observed at Howland and Baker, which indicates recent shark fishing. Sharks and most other large edible fish were relatively rare at Kingman, and sharks are

still depleted at Palmyra, although more abundant than observed in 1998. Recent storm damage was also evident off the north coast of Jarvis and Palmyra.

Midway Atoll

Fish populations have been monitored during surveys of the NW Hawaiian Islands, and the ocean reefs are in excellent condition, but the lagoon reefs are not as flourishing, possibly due to restricted circulation. Reef fish are abundant and healthy, due to fishing restrictions as a NWR.

Fish stocks are in excellent to pristine condition at most of the islands, apart from evidence of recent shark finning and some targeting of large reef fish on the remote reefs, despite being protected as a NWR. Military or USFWS presence at Johnston, Wake, Midway, and Palmyra is discouraging illegal poaching, and giant clam populations are healthy with spectacular densities on Kingman. The only anthropogenic stresses other than fishing impacts (shark finning and depletion of large fish), are vessel groundings, as these low coral islands or atolls are difficult to spot at a distance, and are frequently hit by ships (with associated fuel spills). Marine debris and abandoned fish nets are a major problem at Midway and the other NW Hawaiian Islands, where they become easily snagged, damaging reefs and corals and entangling seabirds, marine mammals, sea turtles and fish. Observations at Palmyra, Kingman, Baker, and Howland in 1998 to 2000 suggest a major bleaching event at these islands in 1997 or early 1998. A major bleaching event was observed at Rose Atoll in April 1994 and at Johnston Atoll in September 1996. Although Howland, Baker, Jarvis, and Rose are no-take NWR, unauthorised fishing probably occurs because they are so remote. Johnston and Midway are limited take NWRs, with on-site management, therefore fish stocks are better managed and abundant. Kingman and Palmyra are proposed as MPAs, but a lack of easy enforcement and surveillance will always put them under threat from over-fishing. Wake Atoll is well protected by the US military. From: Jim Maragos, U. S. Fish & Wildlife Service, Hawaii (jim_maragos@fws.gov), Rusty Brainard, National Marine Fisheries Service, Honolulu (Rusty.Brainard@noaa.gov) and Phillip Lobel Boston University and the Woods Hole Marine Biology Laboratory (pLobel@bu.edu).

Crown-of-thorns Starfish Outbreaks

The last major outbreak of the crown-of-thorns starfish (*Acanthaster planci*) was off the island of Moloka'i in the late 1960s and early 1970s. Lack of *Acropora*, dominance of *Porites* and the island's overall isolation may help to explain the lack of major outbreaks.

STATUS OF CORAL REEF FISHERIES

MHI

There has been a steady decline in abundance of fishes over the past century, with over-fishing listed as the major cause of this decline. Fishing pressure near the heavily populated areas now exceeds the renewal capacity of these resources and the abundance of reef fishes in unprotected areas is much lower than in protected areas. Fisheries catch statistics are unreliable owing to under-reporting by commercial fishers and the large resident

recreational and subsistence fishing population. The recreational catch on nearshore reefs is likely equal to or greater than commercial fisheries catch, and these recreational fishers take more species using a wider range of fishing gear. Hawaii is one of the few coastal states that does not require a saltwater recreational fishing license. The Hawaii Department of Land and Natural Resources is currently expanding its creel program to sample the recreational catch and is also revising existing fishing regulations.

Subsistence fishing is culturally and economically important to many rural communities. In previous times, Hawaiians developed a management system that provided for sustainable harvest of their natural resources. This management put limits on the times and places for fishing based on knowledge of natural cycles and habitats. The Hawaii State Legislature created a process in 1994 to designate community-based subsistence fishing areas and there are efforts currently underway to create such areas on Moloka'i, Kaua'i and Hawaii. Poaching is a recurring problem with the catching of undersized fish and invertebrates and fishing out-of-season contributing to the depletion of coastal resources. For example, in Hanalei Bay, Kaua'i, less than 30% of the omilu (a highly prized jack species) harvested were legal size and only 3% were sexually mature. Currently there are numerous long, cheap gill nets being set deeper and in locations not previously fished (e.g. officials seized 8km of illegal nets from inshore areas over a 6 month period in 1998). Enforcement is poor and fines are minimal, with the few prosecutions not acting as a deterrent to violators of fisheries regulations.

Hawaii provides most of the ornamental fish and invertebrates taken in the USA, because quality is high and the rare endemic species are highly prized. The annual harvest of aquarium fishes rose from 90,000 in 1973 to 422,823 in 1995, with most coming from the island of Hawaii. Commercial permits increased by 39% between 1995 and 1998 and the trade is now having a major impact on both dominant and rare aquarium species. There are no regulations limiting the size, number and collecting season for most species and the full impacts may not be felt yet. Conflicts are common between marine ornamental collectors and subsistence fishers, commercial fishers, environmentalists and the tourism industry. In response, the Hawaii State legislature established the West Hawaii Regional Fishery Management Area in 1998 to improve reef management and declared that 30% of the West Hawaii coastline would be Fish Replenishment Areas (FRAs), where aquarium fish collecting is prohibited.

NWHI

Only commercial fishers with vessels larger than 20m can regularly fish in these remote and exposed waters. Fisheries for bottom fish and lobsters to 100m depth are managed by the NMFS through an advisory body: the Western Pacific Regional Fisheries Management Council (WPRFMC). The abundance of lobsters has declined since the 1980s and the fishery is currently closed. One concern is the impact on the endangered Hawaiian monk seal that consumes lobster in their diet. Resource fish species tend to be larger and more abundant in the NWHI, compared to the MHI. The mean biomass of fish on shallow reefs at French Frigate Shoals and Midway Atoll is almost twice that found in the MHI, probably reflecting lower fishing pressure at these sites. There is minimal collection of corals and aquarium fishes in the NWHI, but there is concern about rare and highly valued species like the masked angelfish (*Genicanthus personatus*), dragon eel (*Enchelycore pardalis*) and the Hawaiian lionfish (*Pterois sphex*).

ANTHROPOGENIC THREATS TO CORAL REEF BIODIVERSITY

Anthropogenic pressures are high on coral reefs of the MHI because most reefs are close to urban centres, but impacts are variable:

Alien Species

At least 19 species of macroalgae have been introduced to O'ahu since 1950 with 4 of these being highly successful and now prevalent throughout the MHI. One alien species, *Kappaphycus alvarezii*, is overgrowing and killing corals in Kane'ohe Bay, some invertebrates have also been introduced, but there are no reports of damage to coral reefs. At least 13 species of marine fishes have been introduced, mostly target species of fishers (6 groupers, 4 snappers, and 1 emperor), with the blueline (*Lutjanus kasmira*) and blacktail (*Lutjanus fulvus*) snapper, and the bluespotted grouper (*Cephalopholis argus*) being the most successful and damaging fish introductions. Other introductions include sardines, herrings, mullet, tilapia and goatfish, which are displacing local species.

Destructive Fishing Practices

Dynamite and cyanide fishing are not problems in Hawaii, but there have been recent cases of chlorine being used to capture lobster or fish. This is highly damaging as it destroys the habitat for all species. Long gill nets are used extensively throughout the Hawaiian Islands and cause localised depletion of fish stocks, including endangered species as bycatch (sea turtles, Hawaiian monk seals), and continual damage to fragile coral colonies through nets being lost, abandoned, or improperly used. State laws require that nets be checked every 2 hours and removed after 4 hours.

Eutrophication

In the MHI, high nutrient levels are known to encourage algal blooms, which can out compete and overgrow living corals. Algal blooms have been a recurring problem on reef flats off the southern and western coasts of Maui for almost 10 years; *Hypnea*, *Sargassum*, *Dictyota* and *Cladophora* have all dominated reef flat areas at various times, presumably due to leaching of nutrients from cesspools, injection wells or other non-point sources. The Federal Clean Water Act requires a National Pollutant Discharge Elimination (NPDES) permit for any pollutant discharged into nearshore waters, and the Hawaii Coastal Zone Management Program and the Hawaii Department of Health are developing a pollution control plan to address discharges not covered under NPDES permits.

Marine Debris

Marine debris from beach goers, storm drains, industrial facilities and waste disposal sites is common on reefs and shores throughout the MHI. In the last 10 years, the amount of derelict fishing gear washing ashore has increased e.g. in 1998, a 3 day community clean up removed over 3,000kg of nets and debris from Kane'ohe Bay and Wai'anae waters.

The major marine debris problem in the NWHI is from derelict fishing gear, including drift nets, trawls, traps and lines. These result in dislodging and breaking of coral colonies, and entangling and killing of seabirds, monk seals, turtles and fish. Drifting marine debris may also serve as a vector for alien species introductions. In 1998 and 1999, NMFS lead multi-agency project teams which removed 39 tons of marine debris from French Frigate Shoals,

Stress and (score)		Hawaii	Maui	O'ahu	Kauai	NWHI
Overfishing	(18)	4	4	5	3	2
Coastal Alteration	(16)	4	4	5	3	0
Tourism	(15)	3	4	4	2	2
Alien Species	(13)	2	4	5	1	1
Urbanisation	(14)	2	4	5	3	0
Marine Ornamental Trade	(14)	4	3	4	2	1
Sedimentation	(12)	1	4	4	3	0
Pollution	(12)	2	3	4	2	1
Destructive Fishing	(10)	2	2	3	2	1
Hurricanes	(10)	2	2	2	3	1
Oil Spills	(9)	1	1	3	2	2
Climate Change	(5)	1	1	1	1	1
Coral Bleaching	(5)	1	1	2	1	0
<i>Acanthaster planci</i>	(1)	0	1	0	0	0
TOTAL IMPACT RATINGS	33	42	52	31	14	12

This is a summary to the major causes of coral reef degradation in the US NE Pacific with 0 = no threat; 1 = low threat; 2 = localised low threat; 3 = average threat; 4 = localised major threat; 5 = general major threat.

Lisianski, Pearl & Hermes and Midway. It is estimated that over 4,000 tons of marine debris still remain in the NWHI.

Military Impacts

The island of Kaho'olawe was used as a military firing and bombing range, which contributed to extensive sedimentation and debris on nearby reef areas. The island is now managed by the Kaho'olawe Island Reserve Commission (KIRC) which is assessing damage and cleaning up debris. Kaula Rock, a small islet located off the southern tip of the island of Ni'ihau, is currently used as a live-firing and bombing target by the US military. Military amphibious vessels have run aground on reefs off the windward side of O'ahu, and last year (1999) a large military troop vessel smashed into a patch reef in Kane'ohe Bay. As with most ship groundings in the MHI, no penalties were assessed or paid. Installation of a US Navy-supported low frequency transmitter near Kaua'i is raising concerns about possible behavioural disruptions to reef fish, turtles, monk seals and humpback whales.

Oil and Chemical Spills

Hawaii has been increasingly reliant on imported crude oil (52 billion barrels/year) for electricity generation and transportation. Large tankers use MHI ports that are immediately adjacent to coral reefs, and there was a 200% increase in the number of oil spills between 1980 to 1990. While 40% of reported spills are small, larger spills have resulted from ship groundings or offloading accidents. In a recent case, an oil spill near O'ahu caused reef damage when it washed ashore 75 miles northwest on Kaua'i. Recent oil spills in the NWHI are almost entirely due to groundings of fishing vessels on the isolated atolls. The October 1998 grounding of a 25m fishing vessel at Kure Atoll released over half of its 11,000 gallons of diesel onto the shallow reef environment.

Given the extensive urbanisation of coastal areas in Hawaii, the number of motor vehicles used on these small islands, and the channelisation of streams and storm drains into nearshore reef environments, the introduction of toxic chemicals (heavy metals, oils, PCBs, PAHs, tributyltin, pesticides and herbicides) in nearshore environments has the potential to affect biodiversity and fisheries stocks. High concentrations of dieldrin and chlordane were found in oyster tissues sampled near stream mouths in Kane'ohe Bay in 1991, five years after their use was banned in Hawaii. In the NWHI, lead and PCBs have been detected in monk seals, possibly resulting from decaying seawalls at French Frigate Shoals and from dumps established by the U. S. Coast Guard in the past. As a response to increasing shore-based chemical spills (e.g. sulphuric acid, PCBs, and refrigerants), the Hawaii Coral Reef Emergency Response Team (HCRERT) is being created to help assess impacts of these events to the environment.

Sediment and Runoff

Sedimentation from runoff continues to be a chronic problem throughout the MHI as a result of poor land-use practices upslope of reefs. Sediment runoff is estimated at more than 1 million tons per year from agricultural, ranching, urban and industrial activities. 'Slash and burn' agriculture (sugar and pineapple) has decreased, and alternatives such as coffee, macadamia, cocoa and fruit trees may also result in a long-term decrease in sedimentation. This decrease, along with the relatively rapid removal of sediments along exposed coasts into deep water by strong current and wave action, will improve conditions for reef growth in the coming decades. Stream channeling, and paving of coastal and upland areas has also contributed to urban impacts on reefs. Two major freshwater kills of corals occurred in Kane'ohe Bay, O'ahu in 1965 and 1987 from '100 year storms'. Salinity within 1-2m of the surface was reduced to less than half (15ppt) for 2-3 days, causing mass mortality of corals and invertebrates on shallow reefs.

Ship Groundings

With over 16,000 commercial and recreational vessels registered in Hawaii, and numerous others passing through the islands, groundings are a persistent problem. A long-line fishing vessel ran aground on a fringing reef of Kaua'i in 1999 and portions of the vessel still remain; no restitution for damage was made. Large inter-island cruise ships make over 400 port calls a year; such traffic is expected to triple in the next 4 years and with it the potential for groundings and spills. Although longline fishing vessels are not allowed to operate within a 50-mile zone around the NWHI, two have run aground on these pristine reefs in the past couple years.

Tourism and Leisure

These constitute the largest industry, employer and revenue generator in Hawaii, with marine tourism bringing in over US\$800 million per year and employing over 7,000 people in over 1000 small businesses. Rodale's Scuba Diving Magazine rated Hawaii as one of the 5 most popular diving destinations in the world, with the small islet of Molokini (and its 1km² coral reef) being rated as the third best dive site in the world for the year 2000.

Damage from tourism activities includes: boating impacts; coastal developments; and overuse of reef resources by commercial dive and snorkel tours. These concerns have triggered limitations on carrying capacity in Hanauma Bay, and restrictions on mooring permits for Molokini e.g. 40 commercial tour boats may be moored at one time. Anchor

damage has been reduced at major dive sites through the installation of day-use mooring buoys by the government and dive industry. New technologies such as tourist submarines, underwater propulsion units, 'seawalkers' (a type of surface-supplied helmet rig), and rebreathers are being introduced without assessment of their potential impacts. Currently there is insufficient monitoring to assess damage and the marine parks do not have resident rangers or managers.

In contrast, tourism activity is minimal in the NWHI. However, the fragile nature of these small reef areas is evidenced by observations that populations of large jacks appear to have been reduced compared to unfished reefs, although the number of visitors are limited and a catch-and-release fishery is encouraged at Midway Atoll.

Urbanisation

Most (85%) of the State's growing resident population resides on O'ahu and Maui. Many segments of coastlines have been extensively altered by filling of reef flats for coastal development and airstrips, dredging of ship channels and harbours, and construction of seawalls. This has resulted in a loss of coastal wetlands and estuaries, which were important fish nurseries. Modifications have increased erosion rates and sedimentation. In contrast, the only recent construction in the NWHI was a Naval Air Station on Midway Atoll and other modifications for military use.

CURRENT AND POTENTIAL CLIMATE CHANGE IMPACTS

Because the location of the Hawaiian chain is favoured by oceanic gyres and deep water surrounding all the islands, these are predicted to be among the last reefs to experience major bleaching events. There were declines in seabirds, monk seals, reef fishes, and phytoplankton in the NWHI in the 1980s, which may have resulted from regional decreases in oceanic productivity caused by climate shifts or decadal oscillations. Early indications suggest that NWHI populations may now be in recovery.

CURRENT MPAs, MONITORING AND CONSERVATION MANAGEMENT CAPACITY

Current MPAs

Hawaiians traditionally closed areas to fishing (*kapu*) to ensure catches for special events or as replenishment areas for regular fishing grounds. Several types of protected status exist today for Hawaiian reefs, including: Marine Life Conservation Districts (MLCDs); Fisheries Management Areas (FMAs); Marine Laboratory Refuge; Natural Area Reserves (NARs); and National Wildlife Refuges. Several no-take MLCDs have proven to increase fish standing stocks, and some less restrictive MLCDs have provided limited protection from fishing, but fish populations have not increased significantly. Other MLCDs are popular tourist destinations featuring fish-feeding and large-scale commercial activities. A FMA on the Kona Coast restricts collecting for the ornamental trade and has increasing stocks of targeted fish species compared to nearby unprotected areas.

MHI

Functional no-take areas account for only 0.3% of the reefs in the MHI. On the island of O'ahu, there are 3 MLCDs and one FMA. Hanauma Bay (41ha) was the first MLCD in 1967 with taking of all marine life prohibited. Pupukea MLCD (10ha) in northern O'ahu, was established in 1983 and permits pole-and-line fishing, spearfishing (without scuba) and collecting of seaweeds, along with the use of gillnets in the northern portion. The Waikiki MLCD (1988; 31ha) is at one end of Waikiki Beach containing a reef flat that has been greatly altered by shoreline construction, beach replenishment, terrestrial inputs and proximity to a large urban population. The Waikiki-Diamond Head Shoreline Fisheries Management Area (FMA) is a regulated fishing area adjacent to the Waikiki MLCD where fishing (but not at night or with gillnets) is permitted only during even-numbered years. Notwithstanding differences in location, size, and habitat type, the completely protected Hanauma Bay MLCD has an order of magnitude higher standing stock of fishes compared with the other areas that had either limited protection or poor quality habitat. Other no-take MLCDs of Hawaii have also been effective in increasing fish stocks. Kealakekua Bay MLCD on the island Hawaii was established in 1969 and Honolua-Mokuleia Bay MLCD on Maui in 1978. All fishing is prohibited in specific sub-zones of these MLCDs and fish biomass has increased steadily since their inception. These examples clearly demonstrate that no-take MPAs with good habitat diversity and complexity increase fish standing stocks.

NWHI

There are several species-specific, limited-take MPAs. The majority of the area is a Critical Habitat for the endangered Hawaiian Monk Seal (*Monachus schauinslandi*). A 50-mile protected species zone is supposed to restrict longline fishing and seasonal area closures prohibited taking lobster until the entire fishery was closed in 2000. The Hawaii Board of Land and Natural Resources will soon hold State-wide public hearings to establish Fishery Management Areas in the NWHI to improve coral reef resource management, including the use of permits to regulate access and manage all activities in coral reef areas in State waters. Recreational and commercial fishing activities are prohibited in the 10-20 fathom isobath of most islands northwest of Kaua'i owing to their status as a National Wildlife Refuge managed by the US Fish and Wildlife Service.

Hawaii Coral Reef Initiative - Research Program (HCRI-RP)

The US government provided funds, through the National Ocean Service (NOS) of NOAA to establish the HCRI-RP as a partnership between the University of Hawaii and the State of Hawaii Department of Land and Natural Resources, Division of Aquatic Resources. The goals are to:

- Assess major threats to coral reef ecosystems, and provide information for more effective management;
- Advance the understanding of the biological and physical processes that affect the health of coral reefs and build management capacity;
- Develop a database to store and access data;
- Conduct public awareness programmes on the threats to coral reefs; and
- Implement education and training for coral reef scientists and managers.

The HCRI-RP has awarded US\$700,000 for research projects in the 3rd year including:

- Continued CRAMP monitoring of coral reef health at sites around the main Hawaiian Islands;
- Continued monitoring of impacts of aquarium fish harvesting on West Hawaiian coral reefs;
- Algal identification and the development of a quantitative sampling method that supports coral reef monitoring;
- Real-time water quality monitoring of some coral reefs and the impact of runoff, using macroalgae as an indicator of pollution;
- Development of a rapid assessment method for describing coral reef resources of the Northwestern Hawaiian Islands (NOW-RAMP); and
- Assessment of effectiveness of marine protected areas to conserve fishery resources and the impact of fishing in a management area.

Past research projects funded by HCRI-RP include:

- Coral Reef Assessment and Monitoring Program (CRAMP);
- Kane'ohe Bay Decision Support System;
- Fine-scale Processes on Hawaiian Reefs involving Fish, Algae & Corals;
- Genetic Variation and Status in Hawaiian Coral Species;
- Impacts of Aquarium Fish Collecting Assessment;
- Effectiveness of Marine Protected Areas Assessment;
- Macroalgal Ecology and Taxonomy Support for CRAMP; and
- Ecological Success of Alien/Invasive Algae Assessment.

Under a separate grant from NOAA-NOS, the State will purchase satellite imagery to support the assessment of coral reef resources in the NWHI discussed above. The grant also provides for the establishment of permanent ecological monitoring sites on Kure Atoll and other NWHI resource areas in subsequent years.

MONITORING PROGRAMMES

In recognition of the major contribution of coral reefs to the Hawaiian economy and the need to provide better information for managers, the establishment of regional monitoring programmes was the focus of a workshop in June 1998. The Hawaii Coral Reef Assessment and Monitoring Program (CRAMP) was developed to describe the spatial and temporal variation in coral reef communities due to natural and man-made disturbances. The partners are the University of Hawaii, the Hawaii State Department of Land and Natural Resources, federal agencies, and NGOs. CRAMP has initiated monitoring at 25 sites on Kaua'i, O'ahu, Maui, Moloka'i and Hawaii, providing a cross section of different reef types across the MHI, and includes impacted and pristine sites. Initial assessments suggest that Hawaiian coral reefs are in better condition than reefs in many other regions. Nine new Fish Replenishment Areas (roughly 35% of the West Hawaii coastline) prohibit aquarium fish collecting and monitoring of reef fish stocks is undertaken every 2 months aims to document the impact of collecting, and the effect of closure on the sites.

PALMYRA ATOLL: JEWEL OF AMERICA'S PACIFIC CORAL REEFS

Palmyra is the second largest US atoll as well as the only undeveloped and unpopulated 'wet' one left in the Pacific. Because of its abundant water, remote location and development potential, Palmyra was threatened with development as a tourism resort, a base for commercial fishing, a refuelling stop for aircraft, a storage site for spent nuclear fuel rods, and a satellite and rocket launching base. So when the chance came to purchase the whole atoll and its incredibly rich biodiversity in early 2000, The Nature Conservancy (TNC) did just that to establish a wildlife sanctuary with some compatible ecotourism. Furthermore, the US Fish and Wildlife Service proposed establishing Palmyra as a National Wildlife Refuge, ideally in cooperation with TNC. Palmyra is a circular string of 50 emerald islets with white sand beaches scattered around aquamarine lagoons with 6,500ha of shallow and deep reefs. It is at the northern end of the Line Islands with the nearest neighbours: Kingman Reef, 50km northwest; and Hawaii 1,700km to the north. It has virtually never been populated, except for visits by voyaging Polynesians and 20 years straddling World War II, therefore the fish and wildlife resources are undisturbed as they have been for thousands of years. That could have changed if 'development' had come with rats, weeds, and shark and cyanide fishing. Palmyra Atoll is in a great location for coral reef biodiversity as it has three times the coral species (135) of Hawaii (and three times more than the entire Caribbean) because it lies in the Inter-tropical Convergence Zone (the doldrums), and receives larvae from all directions, either via the Pacific Equatorial Current, or the Pacific Equatorial Countercurrent. This way it also serves as a natural stepping stone for the marine and terrestrial species that island and reef hop across the Pacific. Major pelagic and migratory fish stocks pass, along with large populations of seabirds, marine mammals, and sea turtles. For example, there are 29 bird species, including some of the largest nesting colonies of red-footed boobies and black noddies in the world, and large nesting beaches for the threatened green turtle. There is also the world's largest land invertebrate, the rare coconut crab, amongst groves of coconut trees. The reefs have amazing populations of fishes that are being over-fished almost everywhere else in the world, as well as rare giant clams, black-lipped pearl shells, and pen shells. Protecting this atoll will conserve all these valuable resources while allowing a small-scale ecotourism operation to ensure that some people can enjoy this gem in the Pacific. From: J.E. Maragos, US Fish and Wildlife Service, Honolulu (jim_maragos@r1.fws.gov)

Populations of the endangered Hawaiian Monk seals and sea turtles have been monitored by the NMFS off French Frigate Shoals, Laysan, Lisianski, Pearl and Hermes, Midway and Kure in the NWHI since the early 1980s. Annual reef fish surveys are conducted at French Frigate Shoals and Midway Atoll, and the reefs are being habitat mapped using towed divers, video cameras and submersibles.

There are many volunteer monitoring programmes including periodic Reef Check assessments on several islands, and impact-specific monitoring by community groups in

the MHI. The DLNR is seeking to coordinate these activities to ensure that data and data-collecting impacts are managed. Part of this effort includes producing the following:

- Best Practices Guidelines: a pamphlet on best management practices for various activities on Hawaiian coral reefs, for direct distribution to the marine tourism industry;
- Visual Impact Cards: use photographs to train divers to identify specific types of coral reef impacts e.g. to distinguish coral disease from fish bites;
- Volunteer Monitoring Techniques Training Manuals.
- NOAA Coral Reef Managers Habitat Classification Workshop: NOS sponsored a Hawaii workshop in 2000 for national coral reef managers to define parameters used to describe reef types and habitats for detailed reef mapping.
- Marine Ecosystems Global Informational Systems (MEGIS) Group: the USFWS formed a multi-agency partnership to create a GIS computer database to share habitat maps and management data for Hawaii and the rest of US Pacific.
- Hawaii Coral Reef Emergency Response Team: the DLNR, with other agency partners is forming a rapid response team to provide resource damage assessment and advice during events e.g. chemical spills, boat groundings, disease outbreaks, etc. The National Fish and Wildlife Foundation has helped equip the team.
- Hawaiian Candidate Species for ESA: the DLNR held a workshop to help develop a proposed list of Hawaiian marine species to submit for Candidate listing under the Endangered Species Act (ESA). Candidate listing helps alert the public, user groups, managers and policy makers of concerns about these species to facilitate voluntary conservation and possible legal listing in the future. The criteria chosen for listing were: restricted range; threats throughout range; limited dispersal; limited reproduction; prolonged time to reach maturity; biological dependency (obligate associations with other organisms); life history characteristics; depleted food-prey; over-fished (includes food, aquarium, research and bioprospecting); and competitive exclusion. Examples of species include: endemic corals with limited Hawaiian range (*Montipora dilatata*, *Porites pukoensis*, *Porites duerdeni* etc.); fish and invertebrates over-fished for food (*Cellana talcosa*, *Epinephalus quernus*, *Epinephalus lanceolatus*, *Scarus perspicillatus* etc.); targets of the marine ornamental trade (*Heteractis malu*, *Centropyge loriculus* etc.); or research (*Lingula reevii*, *Euprymna scolopes* etc.); and habitat-forming organisms of limited range threatened by human activities (*Halophila hawaiiiana* etc.).

GOVERNMENT POLICIES, LAWS AND LEGISLATION

The majority of the coral reefs around the MHI are under the jurisdiction of the State of Hawaii (primarily the Department of Land and Natural Resources). In June, 1998, US President Clinton signed Executive Order 13089 for Coral Reef Protection which mandated that: 'All Federal agencies whose actions may affect U. S. coral reef ecosystems shall:

- identify their actions that may affect U. S. coral reef ecosystems;
- utilize their programmes and authorities to protect and enhance the conditions of such ecosystems; and
- to the extent permitted by law, ensure that any actions they authorise, fund, or carry out will not degrade the conditions of such ecosystems.'

This Executive Order requested that various federal agencies assist State and Territorial resource trustees to protect national coral reef resources. The President also created the US Coral Reef Task Force with cabinet-level appointees charged with implementing the Executive Order.

Recently the US President also directed the Departments of Commerce and the Interior, to work directly with the State of Hawaii (and consult the WPRFMC) to develop recommendations for coordinated management of coral reef resources of the NWHI, and resolve questions of jurisdiction. The State of Hawaii holds trusteeship of all reef resources out to 3 nautical miles from land, and the USFWS administers a National Wildlife Refuge throughout the Islands (with the exception of Kure Atoll). NOAA has authority over most reef resources outside 3 nautical miles primarily through NMFS, with the WPRFMC serving in an advisory role.

Hawaii State Laws and Regulations

The State has laws and regulations on uses and impacts on corals and coral reefs e.g. sand, rubble, live rock and coral are protected from harvest or destruction in State waters, and many Hawaiian stony corals cannot be sold. The State Constitution notes that 'the State and its political subdivisions shall conserve and protect Hawaii's natural beauty and all natural resources, including land, air, mineral and energy sources, and shall promote the development and utilisation of these resources in a manner consistent with their conservation and in furtherance of the self-sufficiency of the State.' In addition, the Constitution states that 'each person has the right to a clean and healthful environment, as defined by laws relating to environmental quality, including control of pollution and conservation, protection and enhancement of natural resources. Any person may enforce this right against any party, public or private, through appropriate legal proceedings, subject to reasonable limitations and regulations as provided by law.' These can be applied to conserve coral reefs. In 2000, a law was enacted banning the harvest of shark fins or export through the State.

Federal Laws and Regulations

A number of Federal laws and regulations apply directly to coral reefs:

- Clean Water Act (CWA) - regulates the discharge of dredged or fill materials into marine and fresh waters; contains provisions governing the filling or draining of wetlands, including seagrass beds, mangroves and salt marshes;
- Coastal Zone Management Act (CZMA) - provides for controlled management and development of shoreline areas through cooperation between federal and state agencies;
- Endangered Species Act (ESA) - provides for monitoring, conservation, and recovery of species listed as either Endangered or Threatened as it relates to the use of federal monies or institutions; and
- National Environmental Policy Act (NEPA) - requires Environmental Impact Assessments (EIAs) or Statements (EISs) for proposed projects that involve federal sponsorship or approval, including coral reef-related projects.

Public Education and Outreach for Coral Reef Protection

The DLNR is producing annual State-of-the-Reefs Reports for distribution to the public, policy-makers and government agencies, and distributes pamphlets on coral reef MPAs, fishing regulations, coral laws and regulations and basic natural history information. There are also public education and outreach projects designed to facilitate coral reef management, including community-based monitoring initiatives, a coral reef awareness-raising campaign, community-based marine debris removal, the installation of day-use mooring buoys at Molokini MLCD, and assessments of marine tourism use of MPAs. The Hawaii Coastal Zone Management Program is supporting research and education on Hawaiian coral reefs and has just produced a new booklet to educate visitors on limiting their damaging impacts.

GAPS IN CURRENT MONITORING AND CONSERVATION CAPACITY

MHI

A primary problem is lack of enforcement of existing laws and regulations, compounded by the lack of specificity in many State and Federal laws and regulations about impacts on coral reefs. Often existing laws are out of date with no mechanisms to deal with new technologies, new uses of natural resources, or over-use of these ecosystems. The Presidential Executive Order to protect coral reefs has yet to make a significant impact in Hawaii; of particular concern is continued government support of economic activities, such as offshore aquaculture, bioprospecting, marine ornamental aquaculture, underwater sensor technology, and shoreline or harbour modification. Current fisheries monitoring provides insufficient information on the large recreational and subsistence fisheries sectors for management. Overuse of MPAs by the tourist industry and a lack of fully protected (no-take) reserves means that there are no coral reef areas in the MHI that are pristine and not exploited. There is a need for a series of fully protected coral reef reserves, however, increasing populations and the proliferation of user groups all demanding access to reef resources, mean that the creation of such new types of MPA are unlikely in the near future.

Ongoing Progress

- The National Ocean Service of NOAA started in mid 2000 to map all shallow (< 20 m) coral reef habitats of the MHI using a specially-outfitted aircraft and will spend the next year producing maps and analyses. These are critical for determining management strategies for these resources;
- The USFWS, the State of Hawaii and the academic community are planning a workshop on alien species for resource managers in mid-2001;
- DLNR is producing a training manual for community volunteer groups on monitoring Hawaii's coral reefs;
- The State, using money from NOAA, is studying the social and economic uses of coral reefs;
- The City and County of Honolulu is constructing a major environmental education centre focused on coral reefs at the county park directly adjacent to the heavily visited Hanauma Bay MLCD; and
- The Waikiki Aquarium and DLNR are attempting to restore damaged coral habitats smashed by large marine tourism vessel moorings in Kealahou Bay MLCD on the island of Hawaii.

NWHI

There are concerns about the effectiveness of multiple agency jurisdiction over one of the last major reef ecosystems in the world that has not been heavily impacted by human activities. Recent Presidential initiatives may be successful in creating the collaboration necessary to protect these resources. A major challenge is patrolling and enforcing regulations over 1600km of the island chain to ensure compliance by fishing, research and ecotourism users. There is a need to create an automated Vessel Monitoring System (VMS), with all vessels carrying transmitters that automatically notify the ship and enforcement authorities of its location in relation to protected areas. Current management is fragmented among agencies with differing missions. Reliance on some agencies to inform others on the management of fisheries resources has had limited success and Federal court action has been required to force the NMFS to comply with fisheries management and endangered species laws. The proposed WPRFMC management plan aims to manage the coral reef ecosystems, yet does not include other fisheries management plans operating in these ecosystems in the proposed measures. Since many coral reef species are listed under existing management plans, the ecosystem approach is subordinate to single-species decision-making. Successful mechanisms like automated VMS, active zoning etc. have not yet been incorporated into proposed regulations.

Ongoing Progress

- The USFWS, DLNR, NMFS, NOS and the academic community will undertake a large-scale Rapid Ecological Assessment (REA) of the coral reefs of the NWHI during September and October, 2000 with 3 teams on 2 research ships. They will assess benthic and fish coral reef resources, map habitat complexity and assess impacts to the ecosystem at all reefs along the 1600km of the NWHI. These results will be used to allow for better management of the coral reef resources;

- DLNR is planning the establishment of a Fisheries Management Area (FMA) for all State waters in the NWHI to protect these unique resources. A State-managed FMA, overlapping and cooperating with the 2 USFWS managed National Wildlife Refuges, will provide better protection for the majority of coral-dominated NWHI coral reefs.

CONCLUSIONS

Coral reefs have always been important for the Hawaiian people, providing food and shoreline protection. The nearshore reefs once provided most of the animal protein and subsistence activities continue, along with commercial, and recreational exploitation and non-extractive activities. Despite this importance, coral reefs are now being degraded in parallel with continued population growth, urbanisation and development. Ocean outfalls, urban and recreational coastal development (hotels, golf courses, etc.) are focal points for coral reef degradation, and new technologies for extraction, offshore aquaculture, and bioprospecting raise concerns about the ability of management agencies to keep ahead of damage to coral reef resources. Short-term economic pressures that ignore the detrimental impacts of development will have severe consequences for Hawaiian coral reefs, which protect shorelines and support the growing marine tourism industry, which is a major component of the economy.

Over-exploitation of most target food fish and invertebrates, and key species for the marine aquarium trade is evident in the MHI. The extent is certainly an underestimate as there is serious under-reporting of current levels of exploitation, further compounding problems for resource management.

The Hawaiian Archipelago reefs constitute the vast majority of US reef area, and Hawaiian reefs contain a high proportion of different reef habitats and endemic species. But over-exploitation, alien species introduction and marine ornamental collection threaten these resources more than in other US coral reef areas.

Hawaii has a wide variety of MPAs which are partially effective in protecting some coral reef habitats, however very few of the reefs (0.3%) around the MHI are fully protected as 'no-take MPAs', where extraction is prohibited. Thus it is going to be extremely difficult to meet the target set by the US Coral Reef Task Force to establish a minimum of 20% of coral reef habitat as 'no-take MPAs' by 2010. Even the few existing MHI 'no-take MPAs' are exposed to heavy human use for recreation and marine tourism, potentially undermining their effectiveness as representing 'natural' coral reef ecosystems. The situation is more promising in the NWHI where anthropogenic pressures are minimal, mainly due to the isolation of these reefs from human populations; however, because corals grow at far slower rates in the NWHI than the MHI, any reef damage in the NWHI is of particular concern.

While new partnerships have been formed by management agencies, academia, NGOs and user communities, there is a need for more financial and political support for the existing and proposed efforts at conserving the exceptionally wide variety of coral reef habitats and resources in the Hawaiian Archipelago.

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